3.6 ELECTROMAGNETIC FIELDS AND ELECTROMAGNETIC INTERFERENCE

This section describes the potential impacts of electromagnetic fields (EMFs) associated with operation of the No Project, Modal, and High-Speed Train (HST) Alternatives. The principal topics discussed in this section are potential impacts on personal health and potential impacts on electronic and electrical devices as a result of electromagnetic interference (EMI).

3.6.1 Regulatory Requirements and Methods of Evaluation

A. REGULATORY REQUIREMENTS

Neither the federal government nor the State of California has established regulatory limits for EMF exposure. The Federal Communications Commission (FCC) regulates sources of radiofrequency (RF) fields to maintain the quality of wireless communications across the spectrum. The FCC, which does not regulate for health and safety, has adopted regulations applicable to EMF exposure that were derived from health and safety evaluations made by the American National Standards Institute/Institute of Electrical and Electronic Engineers (ANSI/IEEE) and the National Council on Radiation Protection (NCRP). FCC regulations would apply to intentional radiators such as the proposed HST wireless systems for both operational and amenity purposes. FCC regulations would otherwise apply only if HST operations (RF interference) interfered with legitimate spectral uses.

Voluntary standards for EMF exposure have been developed by the International Committee on Electromagnetic Safety (ICES), which is sponsored by IEEE. The federal and state governments do not enforce these voluntary standards. The standards are based on studies of electrostimulation (i.e., nerve and muscle responses to the internal electric field in the body). ICES standards recommend maximum permissible 60-Hz magnetic field exposure levels that are a few thousand times higher than 0.3 to 0.4 microtesla (µT) (3 to 4 milligauss [mG]). Magnetic fields greater than 0.3 to 0.4 µT are relatively uncommon exposures that are found in a small percentage of homes that have been shown to have a possible association with childhood leukemia based on inconclusive evidence (National Institute of Environmental Health Sciences 1998, 1999; International Agency for Research on Cancer 2002). Unresolved scientific issues concerning health effects of power frequency extremely low frequency (ELF) magnetic fields were examined extensively by the California Department of Health Services (Neutra et al. 2002) in response to a request from the California Public Utilities Commission. There is no evidence to substantiate a relationship between ELF electric fields and cancer (International Agency for Research on Cancer 2002), and the low-level electric fields typically found in homes have not been associated with other diseases (National Institute of Environmental Health Sciences 1998; Institute of Electrical and Electronic Engineers 2002). The ANSI/IEEE standards; NCRP recommendations, International Commission on Non-Ionizing Radiation protection (ICNIRP) guidelines, American Conference of Governmental Industrial Hygienists, Inc. (ACGIH) guidelines suggest maximum permissible 60-hertz (Hz) electric field levels for public exposure at 4.2 to 10 kilovolts (kV) per meter.

B. METHOD OF EVALUATION OF IMPACTS

The Modal and HST Alternatives were analyzed for EMF/EMI by a search of existing literature and expert opinion (volunteer scientists and engineers from academia and industry working in accordance with IEEE rules) based on that literature. Issues concerning EMF[1] biological and health effects at all frequencies of concern for the HST alternative are the subject of the scientific discipline known as bioelectromagnetics, which is served by The Bioelectromagnetics Society, other scientific organizations, and an extensive scientific literature that has been critically reviewed by scientific expert committees convened by a number of national and international bodies. This body of

[1] EMF covers ELF and RF forms of electric and magnetic fields, and electromagnetic fields.

information is used in this Program EIR/EIS to describe the potential effects for each of the system alternatives. The medical and scientific communities have been unable to determine whether usual residential exposures to EMFs cause health effects or to establish any standard or level of exposure that is known to be either safe or harmful.

3.6.2 Affected Environment

A. STUDY AREA DEFINED

The study area for EMF/EMI associated with operation of the alternatives is limited to potentially affected land uses and populations in the vicinity of the alternative corridors.

B. GENERAL DISCUSSION OF ELECTROMAGNETIC FIELDS

EMFs occur both naturally and as a result of human activity. Naturally occurring EMFs include those caused by weather and the earth's magnetic field. EMFs also are generated by technological application of the electromagnetic spectrum for uses such as the generation, transmission, and local distribution of electricity; electric appliances; communication systems; marine and aeronautical navigation; ranging and detection equipment; industrial processes; and scientific research.

EMFs are described in terms of their frequency, or the number of times the electromagnetic field changes direction in space each second. Natural and human-generated EMFs encompass a broad frequency spectrum. In the United States, the electric power system operates at 60 Hz, or cycles per second, meaning that the field reverses its direction 60 times per second. In Europe, some parts of Japan, and many other regions, the frequency of electric power is 50 Hz. Radio and other communications operate at much higher frequencies; many are in the range of 500,000 Hz (500 kilohertz) to 3 billion Hz (3 gigahertz). In areas not immediately adjacent to transmission lines, 60-Hz EMFs exist because of electric power systems and uses such as building wiring and electrical equipment or appliances.

The strength of magnetic fields often is measured in µT or mG. As a baseline for comparison, the geomagnetic field ranges from 50 to 70 µT (500 to 700 mG) at the surface of the earth. Research on ambient magnetic fields in homes and buildings in several western states has found average magnetic field levels within rooms to be approximately 0.1 µT (1 mG), while measured values range from 0.9 to 2.0 µT (9 to 20 mG) in the immediate area of appliances (Severson et al. 1988, Silva et al. 1988).

Depending on the configuration of the source, the strength of an EMF decreases in proportion to distance or distance squared, or even more rapidly. Because the rate of decrease and the distance at which impacts become insignificant depend on technical specifications such as the source's geometric shape, size, height above the ground, and operating frequency, it is not possible to define a characteristic distance for the extent of field effects that applies in general for all sources. Because of their rapid decrease in strength with distance, EMFs in excess of background levels are likely to be experienced only comparatively near sources. Consequently, only persons on or in close proximity to the proposed HST system would be likely to experience such increases, and while HST operations could introduce some very low but measurable changes in 60-Hz magnetic fields up to 1,000 feet or more from the right-of-way, these low-level changes are not known to be hazardous. ELF is variously defined as having a lower limit of greater than zero (3 or 30 Hz) and an upper limit of 30, 100, 300, or 3000 Hz. The HST catenary and distribution systems will primarily have 60-Hz fields.

In addition to the 60-Hz EMFs generated by the power supply system, the HST Alternative would generate incidental RF fields, and would also use RF fields for wireless communications. The 60-Hz electric and magnetic fields from power-supply systems would occur everywhere near the energized conductors, but only the magnetic fields would vary in strength depending on load. Load would depend on the number of trains in the segment and their operating conditions (acceleration, speed, weight of vehicles, passengers and freight, grade). Hence, in time, the magnetic fields (MFs) are variable, whereas the electric fields (EFs) are constant. Similarly, EFs along the route would be similar for a given distribution and transmission voltage, whereas MFs along the route would depend on nearby loads. Therefore, daily MF averages would differ for different locales because of different local HST traffic. The information presented in this document primarily concerns EMFs at power frequencies of 50 or 60 Hz, and RFs produced intentionally by HST communications or unintentionally by electric discharges (arcing) between the catenary wire and the train's power pickup and other sources of corona discharge typical of high-voltage systems. EMI occurs when the EMFs produced by a source adversely affect operation of an electrical, magnetic, or electromagnetic device. EMI may be caused by a source that intentionally radiates EMFs (e.g., a broadcast station) or one that does so incidentally (e.g., an electric motor).

C. POTENTIALLY AFFECTED LAND USES AND POPULATIONS

Public and occupational exposure to EMFs is widespread and encompasses a broad range of field intensities and durations. Land uses of interest for potential impacts from exposure to EMFs are residences, schools, and daycare centers along the corridors for each of the alternatives. Specialized uses of interest for evaluation for possible sensitivity to EMI are wireless communication, health care, scientific, and military facilities. These facilities may be used for purposes that include public safety, commerce, radio and television broadcasting, scientific research, commercial fabrication, and military testing and operations. The levels of EMF generation are unlikely to impair radio and radar communications at an airport because of the distance between the control tower and the proposed alignments. Transportation alignments may abut property used for educational, medical, religious, and athletic activities. In rural settings, land is largely undeveloped or in agricultural use but can have any of the other uses noted for urban and suburban areas. In addition, transportation passengers and workers would be exposed to EMFs in or below the range of EMFs generated by other rapid transit and electric railroad systems.

3.6.3 Environmental Consequences

A. EXISTING CONDITIONS COMPARED TO NO PROJECT ALTERNATIVE

Under the No Project Alternative, EMFs along existing roadways and railroad rights-of-way would be affected by technological developments in the period before 2020 and by technology- and population-driven changes in total energy consumption. General EMF levels may increase because of massive implementation of low-level RF and infrared for radar and radar-like purposes, as well as possible wireless data transfer for vehicle control by advanced automotive technologies such as collision-avoidance systems and automatic vehicle guidance systems implemented on freeways and highways. Expansion of conventional rail and transit systems using electric propulsion would also increase levels of ELF magnetic fields near new electrical infrastructure. However, any changes in transmission line loads would not directly change residential magnetic fields significantly (Swanson 1996). In addition, the large-scale use of electrically powered automobiles could increase general EMF exposure. The No Project Alternative is not likely to cause significant changes in EMF levels, or human exposure to EMFs or EMI.

B. NO PROJECT COMPARED TO MODAL AND HIGH-SPEED TRAIN ALTERNATIVES

<u>Modal Alternative</u>

Under the Modal Alternative, improvements to airports may increase EMFs because of increased use of radar, radio communications, and instrument landing systems. ELF magnetic fields produced by the electric power system would increase because of additional power used by new or enlarged terminal facilities. However, an expanded airport operation would be local to the facility (control tower) and lines immediately serving it, not a general effect on surrounding neighborhoods or communities (noting that general residential magnetic field exposures are not directly related to transmission line loads) (Swanson 1996). Therefore, the Modal Alternative is not likely to cause significant changes in EMF levels, or human exposure to EMFs or EMI.

High-Speed Train Alternative

Under the HST Alternative, an electrified train system would require delivery of a variable amount of electric power (a maximum per trainset on the order of 10 megawatts) at ± 25 kV of 60 Hz power by an overhead catenary system (OCS) extending the length of the right-of-way. The OCS would be powered from multiple supply substations located near the right-of-way and connected via high-voltage transmission lines to the statewide electric power grid. Two-phase power at ±25 kV would be carried on overhead transmission lines or in cables from supply substations to the OCS. In addition, substations at intermediate locations would serve switching and power boosting functions, although they would not be connected to the power grid. Control, monitoring, safety, and communications systems for railroad operations would use a fiber-optic cable system. Wireless communications would connect trainsets to the fiber-optic cable system. In addition, there would be a standard railroad block control system that would use a small current in the rails to sense train location.

Various components of the HST infrastructure and the trains themselves would be sources of both ELF and RF EMFs. Many of the ELF sources resemble the power lines, substations, and transmission lines used for the statewide electric power system, with the distinction that wayside power uses two electrical phases rather than the three phases that the California and national power systems use. Three-phase 60-Hz power would be supplied from high-voltage transmission lines connected to the power grid for conversion at substations to two-phase ±25-kV, 60-Hz power supplied to the OCS and trains. RF EMF, a principal source of EMI, is produced at the right-of-way by intermittent contact (unintentional arcing) between the pantograph power pickup and catenary wire. RF of this type is characterized by a band of frequencies ranging from kilohertz to megahertz. For transfer of data and voice communications from the fiber-optic trunk to trains in motion, narrow-band RF EMF would be radiated at low power from a lossy coaxial cable or similar antenna design located within the right-of-way. These RF EMFs would resemble, in frequency and field strength, the signals from short-range radio technologies such as walkie-talkies and cellular telephone handsets.

Figure 3.6-1 illustrates overall average magnetic field levels in five frequency bands for 14 transportation systems. Magnetic fields at 50 Hz in a French Train à Grande Vitesse (TGV) vehicle were averaged for measurements made at the head, ankle, and waist of passengers riding in several different vehicles and at several times. The overall 50-Hz magnetic field average was less than 0.5 µT (5 mG). This was several times less than for passengers on a conventional electrified train or electric shuttle bus, but several times greater than for passengers on ferry boats, non-electrified trains, escalators, and people-mover walkways. Localized magnetic fields in an HST vehicle can significantly exceed the overall average. Railroad EMFs decrease with distance from the right-of-way, substation, or power line and have negligible regional or statewide impact.

The HST system would traverse diverse geography and land uses in California with a diversity of potential EMF exposure in urban, suburban, rural, agricultural, and industrial regions. The populations potentially exposed to EMFs from the HST system include passengers, train crew, and other HST workers, as well as people in residences immediately adjacent to the distribution lines or rail line and at adjacent commercial, industrial, educational, medical care, military, and recreational facilities. Present understanding of health effects from long-term exposure to ELF magnetic fields is incomplete but shows that risks to the health of children and adults are either low or nonexistent. Effects of EMI may occur depending on distance to HST facilities and operating conditions. The variable nature of HST power consumption, which changes with operational conditions that include the distance to a moving train, number of operational trains, and train acceleration and velocity, indicates that comparisons to less variable sources of ELF EMF fields may not be appropriate. There is little potential for strong ELF EMFs that can interfere with implanted biomedical devices (cardiac pacemakers, defibrillators, and infusion pumps) to be generated, with the possible exception of potential exposures of HST maintenance workers. For current data and designs, it is not likely that the MF inside an HST vehicle could interfere with even the most susceptible pacemaker. Overall, it can be expected that the HST Alternative would introduce additional EMF exposures or EMI at levels for which there are no established adverse impacts.

3.6.4 Mitigation Strategies

ELF magnetic fields can best be mitigated by design features that reduce fields at the source, but shielding of large sources (bigger than a transformer in a building, or 4 to 8 cubic m) in affected environments would not be not practical. Careful design of the OCS, substations, and transmission lines could reduce ELF magnetic fields to a practical minimum.

Mitigation of ELF electric fields is sometimes possible by changes in the design of the source, and some shielding of a large source can be achieved by increasing vegetation. Relatively effective shielding of 60-Hz electric fields is afforded by ordinary building materials, and very good shielding is afforded by metal panels or screens.

EMI can be reduced at the project level through designs that minimize arcing and radiation of RF energy. Additional mitigation by shielding of sources is not practical, but susceptibility to EMI can be reduced by choosing RF devices designed for a high degree of electromagnetic compatibility. In some cases, electronic filters can be added to attenuate RF EMI. Relocation of receiving antennas and changes in antenna design to models with greater directional gain could mitigate EMI impacts, particularly for sensitive receptors near the HST system.

3.6.5 Subsequent Analysis

The following issues would be evaluated as part of the project-level analysis of an HST system.

- Proximity of occupied structures to high-voltage transmission lines serving supply stations.
- EMFs at passenger stations.
- EMFs in the vehicle compartment. This would require train design to take EMFs into account (e.g., seeking to limit them in the vehicle compartment to the extent practicable and feasible).
- EMFs at specific locations used by the train crew.
- Earth-return currents or power flows in circuits along the rails, where some fraction of the current finds its way back to substation or generating station through the earth for various regions and soil conditions, and the effects of different design and construction practices on these currents. The substations and generating stations would themselves be soundly connected to ground, allowing the earth currents to return there.
- Identification of specific structures (e.g., pipelines, cables, fences) that are particularly susceptible to induced ELF currents and methods for mitigation.
- Identification of receptors (e.g., telecommunications and research facilities) at specific locations with possibly greater sensitivity to EMI impacts.
- Spectral composition of RF generated by the pantograph-catenary contact under operational conditions.

- Technical features (e.g., frequency, field strengths, and modulation system) of the right-of-way-to-train wireless communications system.
- Consider development of an electromagnetic compatibility control plan (as described in APTA SS-E-010-98) to characterize EMI sources, reduction techniques, and susceptibility control procedures (shielding, surge protection, fail-safe circuit redesign, changed location of antennas or susceptible equipment, redesign of equipment, enclosures for equipment); include a safety analysis and failure analysis; and address grounding or shorting hazards.